

Rapid Targeting Technology: Development of the Controlled Reference Image Base

By Ken Koch, Naval Air Warfare Center Weapons Division

Abstract

Rapid and accurate targeting by today's precision strike weapons requires that imagery from intelligence assets, such as unmanned aerial vehicles (UAVs) and manned reconnaissance aircraft, be precisely coordinated with longitude, latitude, and elevation data. This process, called "georeferencing of tactical imagery," was of critical importance to the effective prosecution of targets by Allied forces during the Kosovo conflict.

Engineers and analysts at the Naval Air Warfare Center Weapons Division (NAWCWD) developed a georeferenced database called the Controlled Reference Image Base (CRIB) to register and correlate tactical imagery. The CRIB is derived from the Digital Point Position Database (DPPDB), which is maintained by the National Imaging and Mapping Agency (NIMA). Digital terrain models are extracted from the DPPDB and then integrated with the raw imagery to create ortho-rectified images. In the theater of operations, the CRIB is used with image-correlation software to control the raw tactical imagery. From this controlled imagery, users can quickly calculate, with extraordinary accuracy, the location of items of interest (potential targets, for example) in the tactical imagery.

Because events in Kosovo were driving this development effort, time was a critical factor in completing the task. Relying heavily on the assets of the NAWCWD High Performance Computing Distributed Center, the development team completed the CRIB program in time for it to be used with great success in the Kosovo operations.

This paper describes the process by which the CRIB was developed and examines the control and maintenance software that the CRIB team developed to manage commercial software programs run on the Center's computers.

Georeferencing Tactical Imagery

Modern warfare and the burdens of peacekeeping in the 21st Century have imposed restrictions on our military forces that are more stringent than those of previous eras. In many instances (as seen most recently in Bosnia and Kosovo), air strikes must take place in urban environments, where a very significant military target may be closely surrounded by a noncombatant population. Humanitarian and

political considerations have made the infliction of collateral damage—unintended property destruction or loss of life—a major issue in warfare planning and execution.

Fortunately, the Department of Defense has a variety of weapons with extremely sophisticated targeting and control systems. These weapons are designed for pinpoint accuracy, as witnessed in the “down the air conditioning duct” news clips from the Iraqi Conflict.

Some of these weapons have seekers that allow a pilot to visually guide the weapon to a specified point. Others are in the class of global positioning system/inertial navigation system (GPS/INS) weapons and rely on geographical coordinates to guide them to their targets. Thus the accuracy of the weapon depends on the precision of the coordinates that are programmed into the weapon before, or even during, an air strike. If, for example, a weapon has a guidance error of only 3 meters, but the preprogrammed coordinates have an error of 100 meters, then that weapon could possibly miss the target by 100 ± 3 meters. Ideally, the coordinates are determined with a precision that is greater than the precision of the weapon.

For most fixed, immovable targets, obtaining the necessary highly accurate coordinates is not a significant problem. Satellite or reconnaissance aircraft imagery is gathered, and a slow and methodical strike-planning process is followed. Time is not a particularly vital element in the process; a power plant or railroad bridge isn't going anywhere.

However the problem becomes acute in the area of rapid targeting, also known as time-critical strike. This aspect of air warfare is currently the Navy's number one priority. Many of the most valuable targets for air strikes are either mobile (e.g., Scud launching systems, truck convoys, tanks) or transient (e.g., aircraft on the ground, troop concentrations). The process for neutralizing these time-critical targets begins with locating a potential target, determining that it is in fact engageable, and extracting the required level of precision coordinates from the available data. A strike package is then prepared—essentially a series of target area photos, a brief text description of the target and mission, and the target coordinates—and transmitted to an aircraft in the target vicinity that has the proper weaponry aboard.

Many intelligence assets are available to the strike planners. These range from satellites that gather large amounts of information over broad geographic areas to tactical image-gathering systems (such as aircraft-borne synthetic aperture radar and forward-looking infrared and even weapon seeker video) that concentrate on smaller

areas of coverage. Also available are prebuilt image databases that, used in conjunction with the strategic and tactical imagery, provide highly precise coordinate quality.

Satellite imagery covers a wide area of the battlefield. But by the time it is collected and disseminated to the warfighter, it may be hours or even days old and of little use for finding and attacking time-critical targets.

Tactical imagery, on the other hand, can be in the hands of strike planners within minutes or even seconds of collection. The shortcoming of tactical imagery is that it does not have great geographic precision. While it may be sufficient to identify an engageable target, it will not provide the position information necessary to employ a precision weapon with a high degree of confidence.

Prebuilt imagery products, such as the Digital Point Position Database (DPPDB) prepared by the National Imagery and Mapping Agency (NIMA), often are based on data that are months or years old and therefore are of no value in locating time-critical targets. However these products are extraordinarily accurate and are the ideal source of coordinates for precision guided weapons.

The solution is to merge these three sources to provide location and accuracy, thereby synthesizing the resolution of satellite imagery, the timelines of tactical imagery, and the accuracy of the DPPDB. Through this process, known as georeferencing, targets can be located, identified, and accurately mensurated. And with this capability available to field units, the process can be accomplished in a short enough time that time-critical targets can be engaged and destroyed before they move.

CRIB: Creating a Georeferenced Database

Engineers and analysts at the Naval Air Warfare Center Weapons Division developed a georeferenced database called the Controlled Reference Image Base (CRIB) to register and correlate tactical imagery.

The CRIB is derived from NIMA's DPPDB, which consists of a series of stereo-pair views of the earth. Two images of the same location on the ground are taken from two different points in space. With knowledge of the camera's position and of the pixels that identify the same ground point in each image, a triangulation

equation can be used to determine the three-dimensional (3-D) coordinate of that ground point.

In preparing the CRIB, two types of files are created from the DPPDB data: digital terrain files and ortho-rectified image files. Using a commercially available photogrammetric software program (SocetSet by BAE Systems was used for this project), the stereo images are used to derive 3-D data. The resulting digital terrain files contain elevation posts every 3 meters in both latitude and longitude. Elevation can be determined for every coordinate within the file's bounds (if a coordinate does not fall directly on a given elevation post, it can be interpolated from the surrounding posts).

The second file type, the ortho-rectified image, projects from a flat plane rather than a curved plane such as the earth's surface. This step is necessary because every image taken from any electro-optical sensor (e.g., a camera or infrared seeker) has some amount of distortion—the distance from the sensor to the center of the image is shorter than the distance from the sensor to the far edge of the image.

This sensor-induced distortion results in uneven resolution of all the pixels within the image. In generating the ortho-rectified image, the original image is draped over a terrain file and then a new image is created, with each pixel focused orthogonally to the viewpoint directly above it. Every pixel is also made identical in all dimensions. This process produces a flat, uniform image. In producing the ortho-rectified images, we used the terrain file and one of the images from the stereo pair of the subject area and created an image with 1-meter resolution.

The terrain files and ortho-rectified images comprise the data in the CRIB.

Meeting an Operationally Driven Schedule

In 1999, military operations in Kosovo showed an urgent need to make better use of tactical imagery for prosecuting time-critical targets. To address this need, the National Reconnaissance Organization deployed a developmental program, the Tactical Fusion Prototype (TFP). This program correlates unmanned aerial vehicle (UAV) imagery frames, taken from real-time video, with the highly accurate imagery from the CRIB. The TFP was loaded into several Joint Targeting Workstations (JTWs) and deployed to the Kosovo theater to support U.S. participation in Operations Allied Force and Joint Guardian.

Unfortunately, at that time the CRIB did not cover the intended area of operations, and NAWCWD was tasked to generate CRIB files to fill this gap.

Transferring the DPPDB from NIMA and generating digital terrain and ortho-rectified images require a significant amount of computational time. One terrain file, covering an area of 2 minutes latitude by 2 minutes longitude requires 1 to 1.5 hours on a Sun Ultra 2 300-megahertz processor.

For production purposes, the Kosovo area of operation was divided into 30-minute-square areas called blocks. Filling each block required 225 terrain files and 900 ortho-rectified images. Once a block was defined and the raw data loaded, it would take about 1,687 hours of CPU time to generate the files. On the available dual-processor Sun system, about 35 days would be needed to complete a single block, or about 2.7 years to produce the needed CRIB files. Four extra workstations could be made available, but this would only reduce the production time to 6.5 months (assuming uninterrupted processing, and no errors or anomalies to correct). That time frame would have been inadequate to provide support to the operational forces in Kosovo.

Enter the NAWCC DC

The Weapons Division had recently been selected as the site of a High Performance Computing Distributed Center. The Naval Air Warfare Center China Lake Distributed Center (NAWCC DC) is located in the Integrated Battlespace Arena (IBAR) at the Division's China Lake, California, site. With the arrival of the new computing equipment on base, an enormous amount of computational power was now available.

The local managers of the NAWCC DC cooperated with the CRIB project to rapidly set up an account on the facility's Silicon Graphics Inc. (SGI) Onyx2 Infinite Reality Monster computer systems. SocetSet code was obtained for the SGIs, and software was written locally to manage the file-generation process. The 64 R12000 processors in the NAWCC DC computers, along with other Onyx systems within the IBAR, provided a total of 109 processors available to produce CRIB files. Production began immediately.

To best utilize the NAWCC DC multiprocessors, the software was configured to allow multiple systems to produce data within the same block. Each block was

segmented into modules, with each module consisting of a single 2-minute-square terrain file and the four 1-minute-square image files covering that 2-minute-square terrain file.

Each module was assigned a control file, which was blank to start. As a processor became available, it would open the first blank control file available. The processor would then load a start time and a processor identification code into the file. As each individual CRIB file was completed, the processor would enter the completion time into the control file, and when the entire module was completed, the processor would enter the finish time and close the control file.

A production-process software program developed for each of the computers specified the name of the block that the computer would work on and also set a “quit time,” at which the computer would stop processing. The quit time was used to end processor use in the mornings so that other system users could run their applications without interference from the CRIB production.

During scheduled workdays, only one or two of the NAWCC DC processors would run the CRIB programs. From 6 p.m. until 7 a.m., all 64 processors would run full-time. On weekends, all processors would run continuously until Monday morning. A single production block—1125 files—could now be produced in less than 16 hours, and all 28 blocks for the entire CRIB could theoretically be produced in 28 days.

The speed in file production, however, was now greater than the ability of the CRIB program staff to set up the blocks and perform quality-control checks on the produced data. Three days were needed to prepare a block and load the DPPDB into the program, and 2 days were needed after the processing to perform quality-assurance checks on the data. The data were literally being processed overnight. By staggering the production process and starting a new block every 3 days, total production time for each block averaged 5 to 6 days. The entire CRIB was produced in 4 months.

Successful Employment in Tactical Operations

The CRIB was distributed in sequential releases. Approximately every 3 weeks, the data thus far produced were loaded onto 8-mm tapes and sent to the operational users. Each tape also contained a file listing all portions of the operational area covered by that tape. As they were received, the listings were appended to a master-

list file that described the contents of the CRIB to date. Then this master list was used by the TFP to search for the appropriate files covering an operational area of interest. These data could then be loaded onto the JTW in the field and used on a daily basis.

The TFP program is designed to screen Predator UAV video for potential targets or other features that, for intelligence gathering purposes, require precise positioning information. The JTW operator can digitize views of interest and can enter single frames into the TFP. From the telemetry information that is overlaid on the UAV video, the operator enters additional information into the TFP (type of sensor, location of the airframe, approximate location of the center pointer, size of the field of view). The TFP program then searches the CRIB master list and loads the terrain and image files that cover the area of interest. “Tie points” between the CRIB and UAV images are located, and the TFP then correlates the imagery.

Once this process is completed (which takes only a matter of minutes), the operator can select any point on the UAV frame and the CRIB will provide precise coordinates. The information can be transmitted to the appropriate point—strike planning, intelligence, or even the cockpit of an inbound attack aircraft—for exploitation.

CRIB’s value in the Kosovo operations was not limited to providing weapon-guidance coordinates: it also had applications in intelligence and strike planning. In one incident, for example, a Predator UAV operator observed what appeared to be tactical aircraft being moved from hangars onto roads in adjacent fields. The UAV video was sent in real time to a JTW located in England that was running the TFP. Within moments the operator had extracted the precise coordinates of the aircraft and sent them to a U-2 reconnaissance aircraft ground-station operator. The powerful sensors aboard the U-2 were retasked to image the area, and the U-2 exploitation group specifically identified the aircraft types from that imagery. Target verification data were sent to NATO’s Combined Air Operations Center in Italy, where a JTW, running Target Package Generator software, built a strike package and transmitted it to the cockpit of an F-15E Strike Eagle. The pilot engaged the targets (see Figure 1, taken from weapon seeker video).

CRIB’s utility in the Kosovo operations was directly attributable to its speed of delivery. Using the NAWCC DC, the CRIB data were produced in a timely manner so that the warfighters could apply their tools and technology with precision, speed,

and confidence. Without the computational ability of the NAWCC DC systems, less than half the amount of data actually delivered would have made it into the field.

Figure Caption

Figure 1. Seeker video imagery as weapon approaches target aircraft.



